Health Consultation

Exposure Investigation Report
Dietary Arsenic Exposure Investigation
Hebbronville, Jim Hogg County, Texas

September 7, 2005

Prepared by

Texas Department of State Health Services
Under a Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

Table of Contents

Purpose

The Texas Department of State Health Services (DSHS) investigated dietary exposure to arsenic from consuming rice and beans cooked with municipal tap water in Hebbronville, Jim Hogg County, Texas. DSHS carried out this investigation with support from the Agency for Toxic Substances and Disease Registry (ATSDR).

Background

In August 2003, DSHS used urinary inorganic arsenic and its metabolites as a biomarker to measure exposure to arsenic by Hebbronville residents [1]. At that time, arsenic levels in drinking water ranged from 43.7-52.1 micrograms per Liter (µg/L) [2]. The Jim Hogg County Water Control and Improvement District (WCID) #2, which provides drinking water to Hebbronville, has reported arsenic concentrations in the public water supply ranging from less than (<) 10 µg/L up to 96 µg/L.

DSHS conducted the 2003 investigation [1] in response to community concerns about arsenic levels in the drinking water. DSHS found that two-thirds (⅔) of the people tested had urinary inorganic arsenic levels greater than 10 µg/L, which is a reference concentration for non-occupationally exposed individuals [3]. One-fifth (1/5) of the participants tested had urinary inorganic arsenic levels above 35 µg/L, which may be compared to the Biological Exposure Index[@] established by the American Conference of Governmental Industrial Hygienists (ACGIH) as guidance for assessing occupational exposures to arsenic [4].

Rationale for Additional Investigation

The urinary inorganic arsenic concentrations measured during the 2003 investigation ranged from <2.5 µg/L to 340 µg/L [1]. When corrected for creatinine, the levels ranged from <1.1 to 103.8 micrograms per gram creatinine (µg/g-c). While the wide range of values could, in part, be attributed to individual variations in tap water consumption, the purpose of this follow-up investigation was to explore other potential sources of exposure to inorganic arsenic.

The general population is primarily exposed to arsenic, and arsenic compounds, through consumption of foods, with an average dietary intake of total arsenic (i.e., arsenic in all forms) of about 58.5 µg/day for males and 50.6 µg/day for females. Drinking water can be a significant source of exposure to inorganic arsenic. In general, adults drinking 2 liters of water per day average about 5 µg/day; however, in areas where arsenic is naturally present in the groundwater intakes can range from 10 – 100 µg/day [3]. Based on the results of the initial investigation, residents of Hebbronville who routinely drink the water likely are at the upper end of this range. Food also may be a significant source of exposure to inorganic arsenic. The National Research Council (NRC) estimates that dietary intake of inorganic arsenic to range from 8.3 to 14 µg/day Others have estimated average daily dietary consumption of inorganic arsenic is about 10.22 µg/day, with a range of 0.93 µg/day to 104.89 µg/day [5]. The highest levels of dietary arsenic (in all forms) are detected in seafood, rice, rice cereal, mushrooms, and poultry [5]. Ninety-one percent (91%) of the people living in Hebbronville described themselves as being of Hispanic origin [6]. Since beans and rice are staples of the South Texas Hispanic diet and both absorb water during cooking, we undertook this investigation to assess whether beans and rice prepared with local tap water provided a significant additional source of arsenic exposure.

Methods of Sample Preparation and Analysis

The DSHS staff cooked two batches each of beans and rice in a controlled setting. One batch was cooked using WCID #2 tap water and the other was cooked using distilled water. Cooking utensils, pots, spoons, and measuring cups in order to assure consistency were supplied by DSHS investigators to help assure consistency in sample preparation. The same utensils and pots were used for each batch of beans and rice with appropriate washing between batches.

Staff obtained local cooking methods for beans and rice from people in the community, and were directed by area residents in local preparation methods. The DSHS staff purchased two sets of ingredients from local markets and then worked with community members to cook one batch each of beans and rice at the Hebbronville Apartments recreation room kitchen using WCID#2 tap water. Upon returning to the DSHS headquarters, staff members prepared a second batch of beans and rice using cooking methods consistent with hose used in Hebbronville; substituting distilled water for WCID#2 tap water.

Beans

Prior to cooking the beans, DSHS staff filled a clean plastic container with a known volume of fresh WCID #2 tap water. In a large clean metal pot, DSHS staff combined 3 cups of dry pinto beans, 3 cloves of garlic, and 1,000 milliliters (ml) of the WCID #2 tap water (taken from the plastic container). The ingredients in the pot were brought to a rolling boil, then simmered partly covered.

Staff added additional water to the beans throughout the cooking process to keep the beans covered with liquid at all times; a total of 2.93 L of water was used to cook the beans. After two hours of cooking, one chopped onion was added. After 3½ hours of additional cooking, 1 tablespoon of salt was added and the beans were cooked for one more hour. Identical recipes and procedures were used to cook a second batch of beans at DSHS headquarters using distilled water.

Rice

One cup of *Riceland®* extra long grain rice was browned in 3 capfuls of *Parade®* vegetable oil until most of the grains were light golden brown. Next, staff added 1 8-ounce (oz) can of tomato sauce, 1 cube of *Knorr Caldo de Tomate bouillon®*, and 0.41 L of city tap water to the rice. The mixture was then brought to a boil. The heat was then lowered and the rice simmered until the water and other ingredients were absorbed. Identical procedures were used to cook a control batch of rice at DSHS headquarters using distilled water.

Samples from each batch of beans and rice, and a sample of the Hebbronville tap water were submitted to the DSHS laboratory for analysis. DSHS laboratory analyzed the beans and rice for analysis. The DSHS laboratory measured total arsenic in prepared beans and rice samples using continuous hydride generation atomic absorption spectrometry (GHAAS). The food was digested using the EPA 200.3 method, and analyzed by the Standard Methods 3114C technique. The water sample was analyzed by Inductively-Coupled Plasma-Mass Spectrometry (ICP-MS) using the EPA 200.8 method for total arsenic.

Results

Beans cooked using the Hebbronville city tap water[1] contained 24 µg arsenic per 1-cup serving (by volume) (Table 1). Beans cooked using distilled water contained <11 µg arsenic (<reporting limits) per 1-cup serving (by volume). We estimated the concentration of inorganic arsenic in the beans due to WCID#2 tap water to be 18.5 µg/cup (Table 2).

Rice cooked using the Hebbronville city tap water[1] contained 12.0 µg arsenic per 1-cup serving (by volume) (Table 1). Rice cooked with distilled water contained 6.8 µg arsenic per 1-cup serving (by volume). We estimated the concentration of inorganic arsenic in the rice due to WCID#2 tap water to be 5.2 µg/cup (Table 1).

Table 1. Total Arsenic Concentration (µg per one cup serving)

Media	WCID#2 Tap Water (46.7 µg/L)	Distilled Water
Beans	24	<11
Rice	12	6.8

Table 2. Estimated Inorganic Arsenic Content Due to WCID#2 Tap Water

Food Source	Estimated As Concentration (µg per one cup serving)
Beans	18.5*
Rice	5.2

* Calculated by subtracting ½ the reporting limit for the distilled water analysis from the tap water analysis.

Public Health Implications

The results of this investigation indicate that beans and rice cooked in the WCID #2 tap water absorb measurable levels of arsenic. To assess the potential health risks associated with eating beans and rice cooked in the tap water we used dietary recall data collected during a recent investigation of birth defects along the Texas–Mexico border during which DSHS staff collected dietary information from Hispanic females. Ninety-seven (97%) percent of the 414 females surveyed indicated that they ate beans (burrito or enchilada with beans; taco or tostada with beans; refried beans) anywhere from one to 88 times per month with an average frequency of 18.2 meals per month (Figure 1). Ninety-six (96%) percent of the females surveyed indicated that they ate rice (Spanish rice; any other rice) anywhere from one to 60 times per month with an average frequency of 12.9 meals per month (Figure 2) [7]. To obtain an estimate of the potential contribution that beans and rice consumption might have on inorganic arsenic exposure we

[1] The city tap water contained 46.7 µg /L total arsenic.

assumed one cup as the per meal standard. Using individual dietary recall data from the birth defects study we estimate that inorganic arsenic exposures from eating beans and rice cooked in WCID#2 water could range from 0.17 to 57 µg/day with an average estimated exposure of 13 µg/day (Figure 3). These data suggest that eating beans and rice cooked in the WCID#2 tap water could contribute to an individual's exposure to arsenic.

To assess the potential non-cancer health risks associated with ingesting the inorganic arsenic, both in the food and water, we compared the estimated intakes to EPA's Reference Dose (RfD) for arsenic of 0.3 µg/kg/day [8]. RfDs are based on the assumption that there is an identifiable exposure threshold (both for the individual and for populations) below which there are no observable adverse health effects. Thus, the RfD is an estimate of a daily exposure to arsenic that is unlikely to cause adverse non-cancer health effects even if exposure were to occur for a lifetime. For arsenic, the RfD was derived by dividing the identified no observable adverse effects level (NOAEL) of 0.8 µg/kg/day, obtained from human epidemiologic studies, by an uncertainty factor of three. The lowest observable adverse effects level (LOAEL) associated with these epidemiologic studies was 14 µg/kg/day, where exposure to arsenic above this level resulted in hyperpigmentation of the skin, keratosis (patches of hardened skin), and possible vascular complications [8, 9]. We used standard assumptions for body weight (70 kg adult), meal size (1 cup for adults), and water consumption (2 liters per day) to estimate exposures. For a 70 kg adult, the daily dose of inorganic arsenic received from eating beans and rice could range from 0.002 µg/kg/day to 0.81 µg/kg/day. If an adult were to drink 2 liters of tap water per day in addition to eating beans and rice, the total estimated daily intake of inorganic arsenic could range from 1.33 µg/kg/day to 2.14 µg/kg/day.

The results from this investigation offer no conclusions regarding the relationship between these exposures and the likelihood for adverse health effects, the estimated exposures are 4 to 7 times greater than the RfD and exceed the NOAEL upon which the RfD is based. It is unlikely, however, that the LOAEL would be exceeded. Neither the NOAEL nor the LOAEL represent sharp dividing lines between safe and unsafe exposures. Thus, we assume that the public health significance of the arsenic exposure increases as the estimated doses exceed the NOAEL. Exposure doses 4 - 7 times greater than the RfD and above the NOAEL could be considered unacceptable.

The U.S. Environmental Protection Agency (EPA) also classifies inorganic arsenic as a known human carcinogen on the basis of sufficient evidence from human exposure via long-term ingestion of low levels of arsenic [9]. Arsenic has been associated with an increase in the long-term risk of various cancers. An increase in mortality from multiple internal organ cancers (liver, kidney, lung, and bladder) and an increased incidence of non-malignant skin cancers have been documented in populations consuming water high in inorganic arsenic [5]. Using EPA cancer slope factor, a 30 year exposure scenario, and the exposures estimated above, the estimated excess lifetime risk of developing cancer from these exposures could exceed 1×10^{-4}. Qualitatively this may be interpreted as a low to moderate increased lifetime risk.

Uncertainties

General Uncertainties

Because of the nature of the data used in this report we were not able to estimate exposure with a high degree of certainty. The lack of consumption data specific to this population required us to use dietary recall data from a study of another ethnically similar female population. In general, males eat more than females; thus, it would be reasonable to expect that a 70 kilogram male may be exposed to more arsenic than a 70 kilogram female.

Specific Uncertainties

Considerable controversy also is associated with any estimate of risk, non-cancer or cancer, associated with exposure to arsenic. Both the RfD and the CSF are based on human ecological studies that have recognized uncertainties with respect to the assignation of exposure. Such studies find it difficult to avoid errors in assigning people to specific exposure groups. The studies upon which the RfD and the CSF are based also involved exposure to arsenic in drinking water. The ability of the body to absorb arsenic in water may be higher than the ability of the body to absorb arsenic in food. In our analysis we assumed that the arsenic in the food was 100% bioavailable. Assuming that the applied dose (the amount available for absorption) is the same as the internal dose (the amount that has been absorbed), is very conservative with respect to protecting public health and to some unknown degree overestimates the risk. We did not consider the kinetics of arsenic in the body in our risk estimates. The RfD and the CSF are based on daily exposures over a lifetime. Since the half-life of arsenic in the body (the time it takes one-half of the arsenic to be excreted) is short (40-60 hours), the risk estimates for exposures that occur less frequently than everyday also may result in an overestimation of the risks.

With specific respect to the cancer risk estimates, the mechanisms through which arsenic causes cancer are not known; however, arsenic is not thought to act directly with DNA. Since the studies used to derive the CSF are based on exposure doses much higher than those likely to be encountered at this site, it is questionable whether it is appropriate to assume linearity for the dose-response assessment for arsenic at low doses. The actual dose-response curve at low doses may be sublinear which would mean that the above risk estimates overestimate the actual risks.

Uncertainties Pertaining to Children

The information pertaining to exposure used in this report primarily pertains to adult humans. In an effort to account for children's unique vulnerabilities and in accordance with ATSDR's Child Health Initiative [11] and EPA's National Agenda to Protect Children's Health from Environmental Threats [12], it is important to note that children may be more sensitive to certain toxicants than adults. In communities faced with potential exposure to contaminants, the many physical differences between children and adults demand special emphasis. A child's lower body weight and higher relative intake rate results in a greater dose of hazardous substance per unit body weight. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage. Finally, children are dependent on adults for access to housing, for access to medical care, and for risk identification. Thus, adults need as much information as possible to make informed decisions regarding their children's health.

We also recognize that the unique vulnerabilities of children demand special attention. Windows of vulnerability (critical periods) exist during development, particularly early gestation, but also throughout pregnancy, infancy, childhood and adolescence periods when toxicants may permanently impair or alter structure and function [13]. Unique childhood vulnerabilities may be present because, at birth, many organs and body systems have not achieved structural or functional maturity. These organ systems continue to develop throughout childhood and adolescence. Children may exhibit differences in absorption, metabolism, storage, and excretion of toxicants, resulting in higher biologically effective doses to target tissues.

Conclusions

Eating beans and rice cooked with WCID #2 water would increase exposure to inorganic arsenic, but not at levels that would result in adverse health effects. The total exposure to inorganic arsenic from drinking the water and eating beans and rice cooked in the water likely would not result in adverse health effects. Therefore, DSHS concludes that eating rice and beans cooked with WCID #2 water poses a no apparent public health hazard.

Recommendations

No recommendations at this time.

Public Health Action Plan

Actions Completed

The conclusions of this consultation support DSHS previous health consultation recommendations. The recommendations included the following completed actions:

- DSHS offered retesting to individuals with urinary arsenic levels above 20 µg/g creatinine.
- DSHS provided summary information, answered questions and encouraged concerned individuals to discuss their results and concerns with their personal health care providers. DSHS met with community members, March 2004, to discuss results and address community concerns.

Actions Recommended

None

Actions Planned

The Public Water System plans to increase water production capacity and install a water treatment system to reduce arsenic concentrations in the water system.

Authors

Tina Walker, EMT-I
Health Educator
DSHS Exposure Assessment and Surveillance Group

Nancy B. Ingram, BS
Community Involvement Liaison
DSHS Exposure Assessment and Surveillance Group

Susan L. Prosperie, MS, RS
Environmental Specialist
DSHS Exposure Assessment and Surveillance Group

John F. Villanacci, PhD, NREMT-I
Manager
DSHS Environmental and Injury Epidemiology and Surveillance Branch

Keller A. Thormahlen, MS
Senior Toxicologist
DSHS Environmental and Injury Epidemiology and Surveillance Branch

References

1. Texas Department of Health. Hebbronville Arsenic Exposure Investigation, Hebbronville, Jim Hogg County, Texas. 2003

2. ATSDR/TDH. Data sheets concerning metals levels in Hebbronville water distribution system. Samples collected August 6, 2003, by Karl Markiewicz (ATSDR).

3. Lauwerys R., Hoet P. Industrial chemical exposure, guidelines for biological monitoring. Lewis Publishers. Second Edition, 1993.

4. American Conference of Governmental Industrial Hygienists (ACGIH). Documentation of the threshold limit values and biological exposure indices, arsenic and soluble inorganic compounds. 7^{th} Ed. ACGIH 2001.

5. Agency for Toxic Substances and Disease Registry. Toxicological profile for arsenic (update). Atlanta: US Department of Health and Human Services; 2000 Sept. http://www.atsdr.cdc.gov/toxprofiles/tp2-c5.pdf

6. U.S. Bureau of the Census, Database: C90STF3B. Summary Level: Zip Code 78361. 1990.

7. Texas Neural Defects Project. Department of State Health Services unpublished data; 2005. Kate Hendricks, MD, MPH & TM, Principle Investigator.

8. U.S. Environmental Protection Agency. Integrated Risk Information System. Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office Cincinnati, OH: US Environmental Protection Agency; 1999.

9. Tseng WP, Chu H, How S, Fong J, Lin C, Yeh S. 1968 Prevalence of skin cancer in an endemic area of chronic arsenism in Taiwan. J. Natl. Cancer Inst 40:453-463.

10. Texas Department of Health. Email from Brenda Mokry (TDH Cancer Registry Division) to Dr. Brian Smith (Director TDH Region 11). Jim Hogg County cancer cluster investigation 1992–2001 (Investigation #03029). February 27, 2003.

11. ATSDR. 1995. Child health initiative. Atlanta: Agency for Toxic Substances and Disease Registry, US Department of Health and Human Services.

12. US EPA. 1998. The children's environmental health yearbook. US Environmental Protection Agency.

13. US EPA. 2000. Strategy for research on environmental risks to children. Washington, DC: US Environmental Protection Agency, Office of Research and Development. EPA/600/R-00/068, Section 1.2.

Certification

This Hebbronville dietary arsenic exposure investigation was prepared by the Texas Department of State Health Services (DSHS) under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with methods and procedures approved at the time the investigation was initiated. Editorial review was completed by the Cooperative Agreement partner.

W. Allen Robison

Technical Project Officer, Cooperative Agreement Team, SPAB, DHAC, ATSDR

The Division of Health Assessment and Consultation, ATSDR, has reviewed this public health consultation and concurs with its findings.

Alan W. Yarbrough

Cooperative Agreement Team Leader, SPAB, DHAC, ATSDR

Appendix A - Figures

Figure 1
Number of Meals with Beans Eaten Per Month

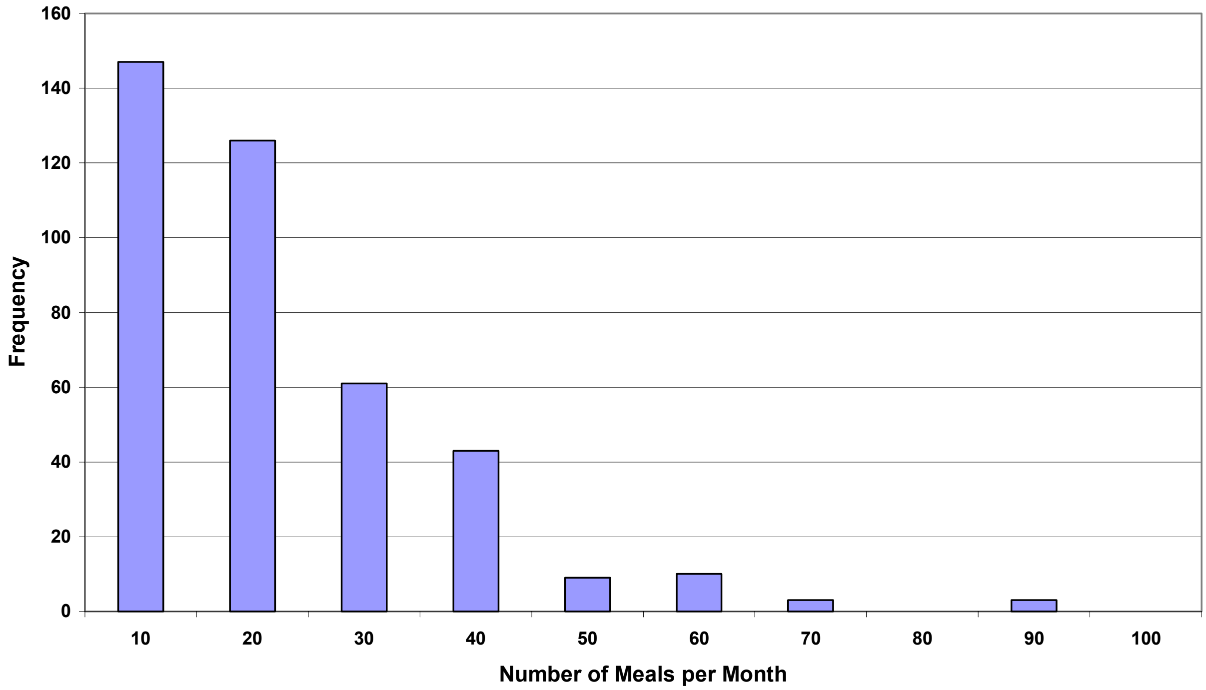

Figure 2
Number of Meals with Rice Eaten Per Month

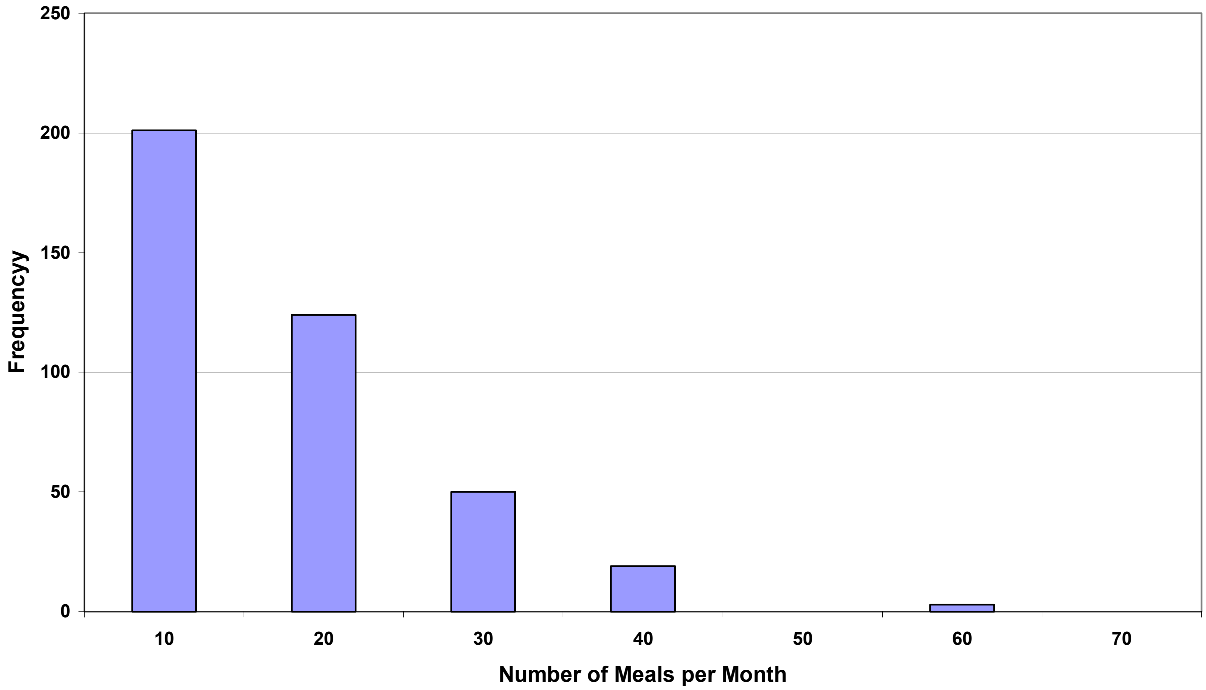

Figure 3
Estimated Daily As Intake (µg/day) From Eating from Beans and Rice